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FINAL REPORT
to
OFFICE OF NAVAL RESEARCH
for
Grant NO0014-86-K-0108

1 February 1986 through 31 January 1988

**Chemistry and Transport in the Middle Atmosphere:
A Simple Interactive Model**

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STATEMENT A
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This grant, NO0014-86-K-0108, supported several research activities at the California Institute of Technology, Division of Geological and Planetary Sciences, in the period February 1, 1986, through January 31, 1988. The overall goal of the research program was the development of a coupled dynamical, chemical, and radiative model of the Earth's middle atmosphere. Two specific tasks were pursued.

First, we developed a coupled 2-D transport and chemistry model utilizing a new algorithm for the transport program module. This scheme was based on work by Prather (*J. Geophys. Res.*, 91, 6671, 1986). Prather's original formulation was extended to account for the sphericity of the atmosphere and to include eddy diffusion and chemistry. Analytic solutions for a series test experiments were developed by which the new numerical procedures could be tested. The results of these experiments show that the upgraded Prather scheme can faithfully preserve sharp gradients, and even discontinuities, in concentration profiles, reflecting the fact that there is essentially no numerical diffusion. In addition, we explored the question of whether horizontal eddy diffusion coefficients for mass transport can be self-consistently estimated by using known fields of zonally averaged temperature and heating.

The second task supported by this grant consisted of the development of an efficient, accurate radiative transfer model of the middle atmosphere. The amplitude of the 2-D transport circulation in the middle atmosphere is proportional to the net diabatic heating rate, Q , which is approximately given by the difference between the solar heating and thermal cooling rates. Because stratospheric temperatures are close to their radiative equilibrium values, Q is usually only 10 to 20% as large as its solar or thermal components. Small errors (10%) in either of these components can therefore produce catastrophic errors in the transport circulation. The radiative transfer that was developed can accommodate all sources of extinction known to be important in the middle atmosphere, including absorption, emission and multiple scattering by N_2 , O_2 , O_3 , H_2O , CO_2 and aerosols. The accuracy of the modeling methods was established from comparisons with more sophisticated multiple scattering models, and line-by-line gas absorption models. The heating or cooling rate errors never exceed 8%, and are usually smaller than 3%.

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PAPERS IN REFEREED JOURNALS:

R.-L. Shia, Y.L. Ha, J.-S. Wen, and Y.L. Yung. Two-dimensional atmospheric transport and chemistry model: Numerical experiments with a new advection algorithm. Submitted to *J. Geophys. Res.*, 1988

CONTRIBUTED PRESENTATIONS AT SCIENTIFIC CONFERENCES:

D. Crisp. An efficient, accurate radiative transfer model of the middle atmosphere. American Geophysical Union Spring Meeting, Baltimore, MD, May 18-21, 1987.

R.W. Zurek, R.-L. Shia, Y. Yung, D. Crisp, and M. Allen. Estimating K_{yy} within the framework of 2-D models. American Geophysical Union Fall Meeting, San Francisco, CA, December 7-11, 1987.